Appendix B: TRMM Ground Validation Science Data Products

Introduction

The NASA TRMM Office has been given responsibility for providing the TRMM Science Data and Information System (TSDIS) with QC'd data (Level 1C-51) from the "Direct Data" sites and the software necessary to produce the TRMM Ground Validation (GV) products, as specified in the "*TRMM Science Data Requirements*," both by TSDIS and the "Direct Product" sites.

Product Descriptions

This appendix provides descriptions of the various GV products, as well as detailing the input, output and data flow necessary to achieve this task. Brief descriptions of the products and their associated data level designations are provided in table B.1.

The TO has also developed several tools of its own for processing and analysis purposes. Where appropriate, these tools are described in some detail, but are clearly marked as TO products or tools.

Level	Description
1B-51	GV calibrated radar data (All data, all recorded fields)
1C-51	Quality controlled radar reflectivity (Max range: 200 km)
2A-52i	Rain existence (Area statistics)
2A-53	Single site rain rate map (2 km x 2 km)
2A-54	Convective / Stratiform map (polar)
2A-55	Single site 3-d reflectivity map (cube)
2A-56	Rain gauge data (one minute average rain rates)
2A-57	Disdrometer data (Date / time stamped spectra of drop sizes)
3A-53	Single site 5-day rain rate map (2 km x 2 km)
3A-54	Single site 30-day rain rate map (2 km x 2 km)
3A-55	3D structure a) Echo area statistics b) Vertical profiles of reflectivity c) CFAD: Array of histograms of Z with height

Table B-1. TRMM GV product data levels and descriptions.

Raw Data

Raw data is considered as that data received by the TRMM Office, directly from the 4 primary sites. Raw data will be delivered on 8 mm tapes and will contain, at the minimum, radar reflectivity and some, all, or none of the following fields: radial velocity and dual polarization reflectivity, and differential phase.

Input data: All data recorded by the radar on an 8 mm tape

Output data:: Same

Processing Flow
1. Record raw data at Ground Validation sites on 8 mm tape
2. Send tape to TO for level 1 for processing
3. TO catalogs scans for level 1B production

1B-51: "GV Calibration"

Product 1B-51 consists of raw radar data in polar coordinate scans at the original spatial and temporal resolution of the data collected by the radar. Data will be reformatted to conform to EOSDIS standard data formats. Two additional procedures will be applied to reduce the data volumes; 1) Scan data beyond 230 km from the radar will not be archived; and, 2) Spectral width data available from the WSR-88D and other Doppler radars will not be archived.

Further, level 1B data is not archived for all the radars but only for the four TRMM primary radars which are processed by TO. A complete description of the GV processing scenarios is included in the "GV Processing Scenarios" section of the "Science Data Requirements." For the four primary sites, TO is responsible for monitoring data receipts and for notifying the appropriate PI or the TO to arrange for retransmission if radar data does not arrive within a preset time limit.

Input data: Raw data from tape

Output data: HDF format disk file

Processing Flow
1. Ingest raw data from 8 mm tape
2. Extract selected fields (reflectivity, radial velocity, and polarimetry).
3. Convert raw data to EOSDIS specified (HDF) format

1C-51: Quality controlled radar reflectivity

Radar reflectivity data quality is diminished by several factors such as ground clutter, anomalous propagation, second trip echoes, spikes (due to radio and/or solar interference), clear air echo, and random noise. These spurious echoes must be removed from the data before reliable application of any of the subsequent GV algorithms can be attempted. The purpose of this product is to serve as input for the following radar derived products: 2A-53 ("Radar Site Rain Map"), 2A-54 ("Radar Site Convective-Stratiform Map"), and 2A-55 ("Radar Site 3-D Reflectivities"). The 1C-51 data is at the same temporal resolution as the 1B-51 data; however, the data will be truncated at 200 km.

The Level 1C-51 quality-controlled product consists of the following fields:

a) Uncorrected reflectivity (as in 1B-51, but range truncated @ 200 km);
b) Uncorrected reflectivity quality control *mask* (see note below);
c) Differential reflectivity (as in 1B-51, but range truncated @ 200 km);
d) Differential reflectivity quality control *mask* (see note below).

NOTE on *masks*: There are three possible modifications to the uncorrected reflectivity (dBZ) or differential reflectivity (ZDR) data that must be flagged:

a) No correction necessary;
b) Deletion of point entirely;
c) A (+/-) adjustment to the recorded value.

QC_Value	Meaning
-99	Delete point entirely
-10 to +10	Add this QC_Value to this point
99	Point needs no correction

It has been suggested that the points masked for deletion be assigned a quality assurance value, such that -99 means the point is bad, and, say, -90 means that there is reason to suggest that the point should be deleted, but is considered a borderline case. This is subjective and needs to be discussed further, but may help investigators working with the data sort out the good/marginal/bad data.

Input Data :
1B-51

Output Data:
1C-51

Processing Flow
1. Load 1B-51
2. Perform Quality Control on radar reflectivity using automated technique to remove ground clutter, anomalous propagation, double trip echoes, spikes and other noise, and, clear air echo.
3. Create quality control mask and correction mask from results of 2.
4. Write reflectivity fields, with associated masks to HDF file.
5. Deliver 1C-51 data to TSDIS for product processing.

2A-52i: Rain existence

This product will provide information on the areal distribution of reflectivity in the low level 1C-51 data. This algorithm uses 1C-51 data as input to determine the fraction of the radar FOV which has measurable precipitation (as defined by the dBZ field exceeding a set threshold). This product is not intended for scientific purposes, but as metadata to enable queries of coincident satellite data with GV products containing at least a specified amount of rain.

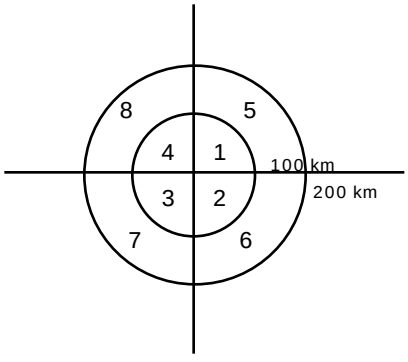
Input:: 1C-51 reflectivity

Output:: Percent of raining area of low-level radar scan, as proxied by the area of the radar scan with reflectivities above a given threshold.

Processing Flow

1. Load 1C-51 radar data tape
2. Load reflectivity volume into memory
3. Compute fraction of area > threshold reflectivity
4. Write fraction to disk file, labeled by time.

NOTE: The TRMM Office uses a similar approach in its data processing, but also computes the fraction of area above a given threshold for sectors of the radar domain. The fraction of reflectivities above some specified threshold within the lowest sweep will be computed within sectors of 100 km x 90 degrees. Thus, there will be eight such sectors (see figure below) and the 2A-52i product will return the appropriate fractional area for each sector. This information can then be used to determine whether subsequent processing of the 2A-53, 2A-54, 2A-55 products should be made.



2A-53: Radar site rain rate map

This product represents the instantaneous rain rate maps produced from the 1C-51 data. These products require the application of appropriate Z-R transformations, which may themselves depend on the type of rainfall (e.g., stratiform, convective). The CAPPI reflectivities will first be converted to rain rates, then a polar-Cartesian transformation will be applied. Discussion of the interpolation routines is under way. The resultant rain maps will be 2 km x 2 km CARPI's (constant altitude rectangular position images).

Input Data
Coincident 1C-51 and 2A-54 products

Output Data:
2A-53: 2 km x 2 km CARPI of rain rates to 200 km from radar

Processing Flow
1. Load 1C-51 radar data tape
2. Load reflectivity volume into memory
3. Convert reflectivities to rain rates
4. Apply polar-Cartesian transformation with rain rate field
5. Return 2 x 2 km CARPI containing rain rate
6. Output to HDF file.

2A-54: Radar site convective/stratiform map

The convective / stratiform separation is based on a user-specified dBZ threshold applied to a low-level reflectivity sweep. For each point on the reflectivity map, if the reflectivity value is missing or below minimum detectable signal (MDS), a rain type of "no echo" is assigned. Otherwise, if the reflectivity value is less than the user-specified threshold value, a rain type of "stratiform" is assigned, and if the reflectivity value is greater than that threshold value, a rain type of "convective" is assigned.

Input Data
1C-51

Output Data
2A-54: Sweep or CARPI. Serves as partial input to 2A-53 and 2A-55.

Processing Flow
1. Load the 1C-51 radar data
2. Load the reflectivity volume into memory
3. For each point in the lowest sweep in 1C-51 data, determine whether a given pixel is associated with convective rain, stratiform rain or no echo.
4. Return S / C mask in HDF format. This map has the same dimensions and resolution as the lowest sweep of the reflectivity volume.

2A-55: 3-D radar reflectivities

This data are the Cartesian transformation of the 1C-51 data and will be used for comparing it with other TRMM data using NCAR's Zebra software. The data will consist of several levels of 2 km x 2 km CAPPI's (constant altitude PPI) from, say every 2 km vertically, starting at 2 km above ground level (AGL) to 20 km AGL. Discussion of the interpolation method is in progress.

Input Data
1C-51

Output Data
2A-55a: Cube (1.5 km - 22.5 km x 1.5 km cube)
2A-55b: Vertical profile (1-d array by height of mean Z)
2A-55c: CFAD (Array of histograms by height)

Processing Flow
1. Load the 1C-51 radar data
2. Convert the spherical data into Cartesian (3-dimensional) data.
3. Output to HDF file

2A-56: Rain gauge data

Each of the TRMM Ground Validation sites will contain a network of one or more rain gauges and possibly other sensors for measuring rain intensities. Each such dataset, potentially, will be in a unique format (but all will probably arrive on floppy disk or via network) and thus will require some re-formatting prior to the 2A-56 production. Once the data has been reformatted, the TRMM Office will provide the data as one (1) minute average rain rates for each gauge separately. The one minute rain rate files will contain header information describing the gauge site, type and location, followed by the time-stamped rain one minute rates. Also, when available, the peak 1-min rain rates will also be included in the 2A-56 product.

Input Data
Raw gauge data on floppy disk or obtained via network

Output Data
2A-56: TRMM Office GMIN files (1-min average rain rates)

Processing Description
1. Load raw gauge data from floppy
2. Re-format into TRMM Office standard gauge file format
3. Using a spline interpolation or other method to create one minute average rain rates
4. Output to HDF file

2A-57: Disdrometer data

Several of the key TRMM Ground Validation sites will contain one or more disdrometers for measuring the drop size distribution (DSD) of rain drops. The data will most probably arrive on floppy disk in binary format. The data till be reformatted into a time / date stamped ASCII file containing approximately 20 channels of counts of raindrops within each size class. Additional computed parameters will also be supplied, including R, Z, N_o, m and Λ. Where R is rain rate [mm hr^{-1}], Z is reflectivity [mm^6 mm^{-3}], and N_o , m and Λ are the gamma distribution parameters given by: $N(D) = N_o D^m e^{-\Lambda D}$.

Input Data
Raw disdrometer data on floppy disk or obtained via network

Output Data
2A-57: TRMM Office DSD files, with one minute drop size spectra, rain rate, reflectivity and gamma distribution parameters.

Processing Description
1. Load raw DSD data
2. Re-format into TRMM Office standard DSD file format
3. Compute and add to the DSD file, the rain rate, reflectivity and gamma distribution parameters
4. Output to HDF file

3. Using the 2A-54 products (stratiform/convective maps) in conjunction with the 2A-53 rain rate maps, re-calculate the contribution from each rain type and compute the average hourly rain rate for the period for convective and stratiform rainfall.
4. Output to HDF file

3A-54: 30-day site rainfall map

The purpose of this product is to verify products 3B-42 (Rainfall map from TRMM data combined with GPI) and 3B-43 (Rainfall map from TRMM data combined with SSM/I and other data sources). The 3A-43 algorithm sums the data from the individual volume rainfall maps (2A-53 product) into 30 day totals. Then, using the 2A-54 maps with the 2A-53 maps, it separates the maps into their convective and stratiform components to compute the respective convective and stratiform average rain rates for the period.

Input Data
Time series of 2A-53 and 2A-54 products for the period

Output Data
5 day rain accumulation (CARPI).

Processing Description
1. Load time series of 2A-53 products
2. Sum the time series of 2A-53 products and compute the average hourly rain rate for the period
3. Using the 2A-54 products (stratiform/convective maps) in conjunction with the 2A-53 rain rate maps, re-calculate the contribution from each rain type and compute the average hourly rain rate for the period for convective and stratiform rainfall.
4. Output to HDF file

3A-55: 30 day 3-D structure
This product can be broken into three parts: 1) echo area statistics (TBD); 2) mean vertical reflectivity profile; and, 3) histograms of reflectivity with height. The echo area statistics are TBD. The mean vertical profile provides the mean reflectivity as a function of height over the 30-day period. The histograms provide information on the frequency distribution of reflectivity with height, referred to by Houze et al. (BAMS; 1995) as Contoured Frequency by Altitude Diagrams (CFAD). The stratiform and convective contributions to the 3-d structure are also calculated via incorporation of the 2A-54 products (or intermediate products calculated with them).

Input Data
Time series of 2A-54 and 2A-55 products

Output Data:
a) 30-day echo area statistics
b) 30-day mean vertical reflectivity profile
c) 30-day CFAD

Processing Description
1. Load time series of 2A-55 products
2. Computer 30-day echo area statistics (TBD)
3. Compute 30-day CFAD
4. Compute 30-day vertical reflectivity profile
5. Output to HDF files